CHINA-ITALY BILATERAL SYMPOSIUM ON THE COASTAL ZONE: EVOLUTION AND SAFEGUARD

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IN SITU TREATMENT OF CONTAMINATED WATER ENVIRONMENTS: THE EXPERIMENT OF THE ARSENALE VECCHIO, VENICE LAGOON, ITALY.

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Abstract

We report on the results of an experiment of in situ bioremediation by forced aeration, carried out in the Arsenale Vecchio shipyard dock basin of the Venice Lagoon, Italy. The experimental area is characterized by its limited size and reduced boat traffic.

The forced aeration technique chosen for the oxygenation of the highly polluted bottom sediments and of the water column above does not obstruct harbor activities and is unique due to its innovative use of a system of porous pipes laid on the bottom sediments.

The general recovery of the polluted shipyard dock basin resulted in the documented return of small fish to the area as an indication of a less polluted environment. Most important the bioremediation of the water body above the bottom sediment favours, with time, the formation of a clean natural sediment capping over the bottom contaminated sediments. Post-experiment control after fifteen months of aeration with no extra oxygen added, shows the presence of clean light grey sediments with no foul septic smell, deposited over the polluted bottom sediments. The experiment has indicated that oxygenation by porous pipe forced aeration could represent a cost effective and environmentally feasible way for the recovery of shallow marine and fresh water systems, in situations where other techniques may not be economically and/or environmentally feasible.

Keywords: *bioremediation, forced aeration, surficial sediments, heavy metal contamination, Venice Lagoon*

INTRODUCTION

Intense industrialization and urbanization of shallow water systems have caused an increasing environmental hazard that urgently requires the development of new cost effective and environmentally feasible technologies in order to reduce the high level of pollutants in both fresh and marine ecosystems. Different techniques have been

developed for the environmental recovery of shallow marine and fresh water bodies, in particular in coastal areas: dredging and removal of contaminated sediments, dredging and in-situ chemical treatment, capping with a 20 to 60 cm layer of inert material, in situ oxygenation by forced aeration, and so forth. The choice of the proper technology for the remediation of polluted water bodies should consider: the environmental characteristics, the physical characteristics of the sediments, the type of contaminants, the environmental feasibility, the long-terms results and the costs.

Of the different techniques available, oxygenation by forced aeration represents a promising approach, with almost immediate results. Forced aeration consists in the introduction of a great amount of oxygen at the sediment-water column interface with the aim of stimulating aerobic bacterial communities to create an environment suitable for the biodegradation of organic and inorganic pollutants (Bonardi et all, 2004).

Following the indications given by several experiments of bioremediation carried out in different water coastal environments a new innovative technique of oxygenation by forced aeration through a porous pipe system have been applied for the in situ recovery of the Arsenale Vecchio shipyard dock basin of the Venice Lagoon.

STUDY AREA: THE ARSENALE VECCHIO DOCK BASIN

The Arsenale Vecchio shipyard dock basin (Fig.1) was chosen for this experiment because of its limited size and reduced boat traffic. Located in the eastern part of the Venice urban area, covers an area of about 46 ha, of which 11 ha are water with a depth varying from -1.50 m to -5.0 m. The Arsenale Vecchio dates back its origin to the XI century when shipyard activities started with pick expansion during the XV century. Presently is under the Italian Navy jurisdiction.

The sediments underlaying the Arsenale area, as for the Venice Lagoon, consist mainly of a sequence of unconsolidated sand, silt, clay and peat layers. Mud layers with different level of consolidation are also present within this sequence (Bonardi et all, 2003). Present bottom sediments of the Arsenale basin consist of the original marine-lagoonal sediments mixed with contaminated landfill material from the adjacent reclaimed marsh and with the contaminated

material from the past shipyard activities and from the more recent Navy operations.

THE FORCED AERATION SYSTEM

The forced aeration apparatus used for this experiment was supplied by SAPIO Industrie s.r.l. and consists of: a) a 20,000-litre cryogenic evaporator, positioned on the dock adjacent to the experiment area, b) a main distribution conduit (Fig.2) and c) a set of 19 porous pipes 21 m long (Fig.3) laid on the bottom floor of the basin. The porous pipe system is laid on the surface of bottom sediments in contact with the water column above, therefore any possible sediment mixing that may occur caused by the oxygenated air from the porous pipes is limited to the top 5-10 cm and can be easily reduced to a minimum. The gas from the liquid oxygen was automatically distributed during the night through the porous pipes, from June to December 2005.

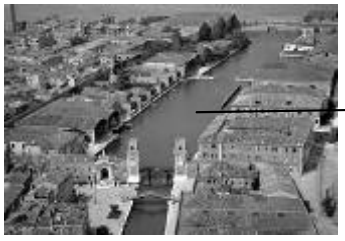


Fig. 1 - The Arsenale Vecchio shipyard

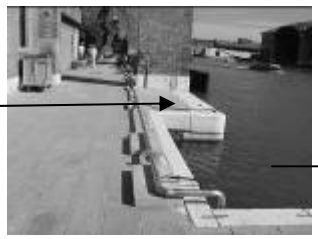


Fig. 2 - The distribution conduit.

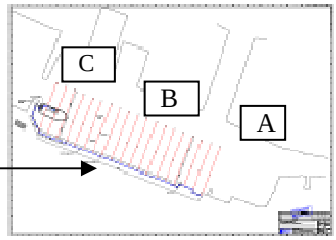


Fig. 3 - The porous pipe aeration system and core sites: A, B, C.

The forced aeration with air only and no liquid oxygen added was continued for additional 15 months in order to monitor the variation, with time, of the aeration effect at the sediment-water column interface.

Following a preliminary sedimentological investigation of the experiment area, a set of 3 cores 50cm long was collected just before (A2, B2, C2), during (A3, B3, C3) and just after (A4, B4, C4) the 6 month oxygenation campaign and after the 15 month aeration campaign (A5, B5, C5) with air only.

The sediment cores were carefully kept upright and frozen in order to avoid any artificial mixing of the top part that, being in contact with the water above, is very fluid and mixing could easily occur.

Following a detailed description of their lithology, stratigraphy, colour variability and macrofossil content, the frozen cores were sliced every 2 cm for the top 20 cm for grain-size, mineralogical and geochemical composition determination using a Fritsh Analysette 20 SediGhraf, an X-ray diffractometer and an Inductively Coupled Plasma Mass Spectrometer (ICPMS) respectively.

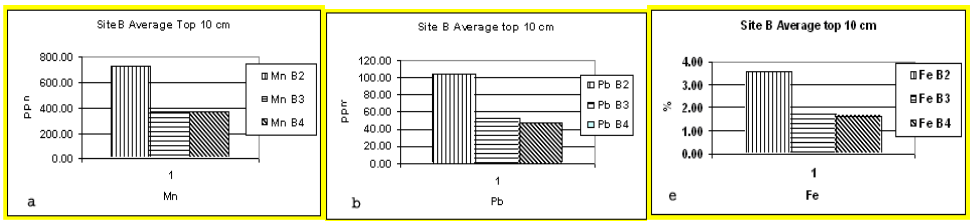
RESULTS AND DISCUSSION

All sediment samples from the three coring sites are very similar in grain-size. Grain-size varies from sandy-silt to clayey-silt to silty clay. The average mineralogical composition is also very similar in all samples, with dolomite prevailing over calcite and quartz as major components, while muscovite, ankerite, plagioclase, kaolinite and gypsum are the minor components.

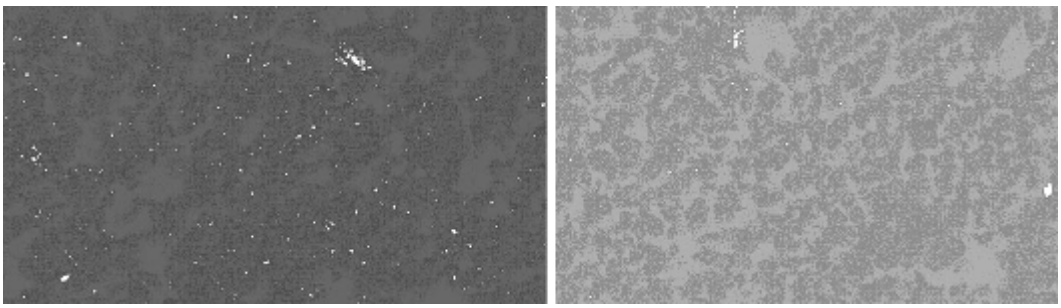
In general the down core variations of the major and minor heavy metal contents are limited to the top 15-20 cm. As expected the effect of forced oxygenation is also limited to the 10-15 top cm of the sediment cores. The comparison between the averages of the heavy metal content in the top 10 cm of each core collected just before, during and just after the aeration campaign shows a general negative trend (Figures 4a, b, c). The impact of forced oxygenation, as expected, is higher on the sediments from core B located close to the porous pipe system, while samples from the farther located sites A and C show a lower effect of the forced oxygenation.

Detailed SEM-EDS (Scanning Electron Microscope equipped with an Energy Dispersion Spectrometer) investigation of the topmost 2mm sediments of each core, at the interface water/bottom sediments where the effect of forced oxygenation is more direct, has given interesting results with regards to the presence of framboidal pyrite micro-crystals. Framboidal pyrite is in fact characteristic of an anoxic environment. According to Deer, Howie and Zussman (1966) “raspberry-like aggregates of tiny spherical particles of pyrite are referred

to as framboidal and their presence in sediments has been attributed to the action of micro-organisms, or sometimes to colloidal deposition". The SEM-EDS pictures (Fig.5a) of a top 2mm sample (B3-0) from site B obtained during the aeration shows abundant granules (white spots) of framboidal pyrite while, as effect of the oxygenation, fewer granules are present in the sample (B4-0) (Fig.5b) collected after 40 days at the end of the aeration. A further evidence of the environmental recovery of the Arsenale Vecchio shipyard basin is given by the return of small fish (Acquatelle) in the experiment area. Past experiment control, after fifteen months of aeration with no extra oxygen added, shows the presence of clean light-grey sediment, with no foul septic smell capping the contaminated bottom sediments.



Figures 4a, b, c, - Some examples of heavy metal variations following the oxygenation by forced aeration.



5a B3-0 5b B4-0

Figures 5a, b - Photo 5a: the topmost sample B3-0 taken during of the aeration campaign, Photo 5b: the topmost sample B4-0 taken just after the aeration campaign. High resolution X-ray map of Sulphur (S) (bright spots). The Sulphur bright spot are less abundant in Photo 5b as effect of the aeration. All spots checked by EDS: the chemistry is Fe and S (Pyrite)

CONCLUSIONS

The oxygenation of the Arsenale Vecchio shipyard basin by means of a porous pipe forced aeration system has indicated that: a) is effective in reducing the heavy metal content in the top surficial sediments; b) is also effective in the

recovery of the water body above; c) is not obtrusive, allowing the daily normal navigation; d) its effects occur within six months of oxygenation; e) bottom sediment mixing is reduced and limited to the top 5-10 cm; f) forced aeration through a porous pipe system could represent a cost effective way of environmental recovery in situations where the removing of contaminated bottom sediments may not be feasible; g) the bioremediation of the water body above the bottom sediment favors, with time, the formation of a natural capping of clean sediments over the bottom contaminated sediments.

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REFERENCES

Bonardi M., Donnici S., and Serandrei R. (2003). New data on depositional environments in late Quaternary sediments underlying the Arsenale Area, Venice Lagoon, Italy.*GAC-MAC Vancouver May 25-28-2003.*

Bonardi M., Ravagan G., Morucchio C., Tosi L., Almeida P. and Desanctis S., 2004. Environmental Recovery of Coastal Areas: The Bio_2Remediation Study Case of the Industrial Harbour of Marghera, Venice, Italy. *Journal of Coastal Research, SI 39 Proceedings of the 8th International Coastal Symposium), pg1044-1048pg. Itajaí, SC – Brazil, ISSN 0749-0208.*

Deer, Howie and Zussman , 1966. An Introduction to the Rock Forming Minerals. *Longmans, Green and Co. LTD.*